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Prevalence of Shoulder Arthroplasty in the United States and the Increasing Burden of Revision Shoulder Arthroplasty

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Investigation performed at Emory University, Atlanta, Georgia

Background: Existing data on the epidemiology of shoulder arthroplasty are limited to future projections of incidence. However, the prevalence of shoulder arthroplasty (the number of individuals with a shoulder arthroplasty alive at a certain time and its implications for the burden of revision procedures) remains undetermined for the United States. Hence, the purpose of this study was to estimate the prevalence of shoulder arthroplasty in the United States.

Methods: The National Inpatient Sample (NIS) was queried to count all patients who underwent total shoulder arthroplasty (TSA), including both anatomic and reverse TSA, and hemiarthroplasty between 1988 and 2017. The counting method was used to calculate the current prevalence of TSA and hemiarthroplasty using age and sex-specific population and mortality data from the U.S. Census Bureau.

Results: In 2017, an estimated 823,361 patients (95% confidence interval [CI], 809,267 to 837,129 patients) were living in the United States with a shoulder replacement. This represents a prevalence of 0.258%, increasing markedly from 1995 (0.031%) and 2005 (0.083%). Female patients had a higher prevalence at 0.294% than male patients at 0.221%. Over 2% of people who were ≥80 years of age in the United States were living with a shoulder replacement. Furthermore, approximately 60% of patients living with a shoulder replacement had undergone the operation between 2013 and 2017. The incidence of revision shoulder arthroplasty is increasing on an annual basis, with 10,290 revision procedures performed in 2017, costing the U.S. health-care system $205 million.

Conclusions: The prevalence of shoulder arthroplasty in the United States has markedly increased over time. This trend will likely continue given increasing life expectancies and exponentially increasing shoulder arthroplasty incidence rates. Most patients do not have long-term follow-up, and revision shoulder arthroplasty rates are increasing, a trend that is projected to continue. The data from our study highlight the enormous public health impact of shoulder replacement and shed light on a potentially increasing revision burden.

Over the last several decades, shoulder arthroplasty has continued to evolve. Hemiarthroplasty and total shoulder arthroplasty (TSA), both anatomic[1] and reverse[2], have been shown to provide substantial pain relief and functional benefits[3,4]. The United States has seen a dramatic increase in the utilization of TSA over the past decade, likely due to expanding use, indications, and familiarity with the reverse TSA[5-12]. Although the current and projected future incidence (i.e., annual procedural volume) of shoulder arthroplasty has been investigated[12], there remains a paucity of information with regard to the prevalence of shoulder arthroplasty (i.e., the portion of the population living after having undergone a shoulder arthroplasty at an earlier point in time) and the incidence of revision shoulder arthroplasty.

Prevalence represents an important epidemiological parameter to quantify. Understanding prevalence provides a more complete picture of the impact that shoulder arthroplasty has and will have on the population and health-care policy. In a recent study, Maradit Kremers et al.[13] found that the prevalence of hip and knee arthroplasty is relatively high and will continue to rise. In their study, demand by young patients, coupled with increasing life expectancy, contributed to this trend[13]. Although shoulder

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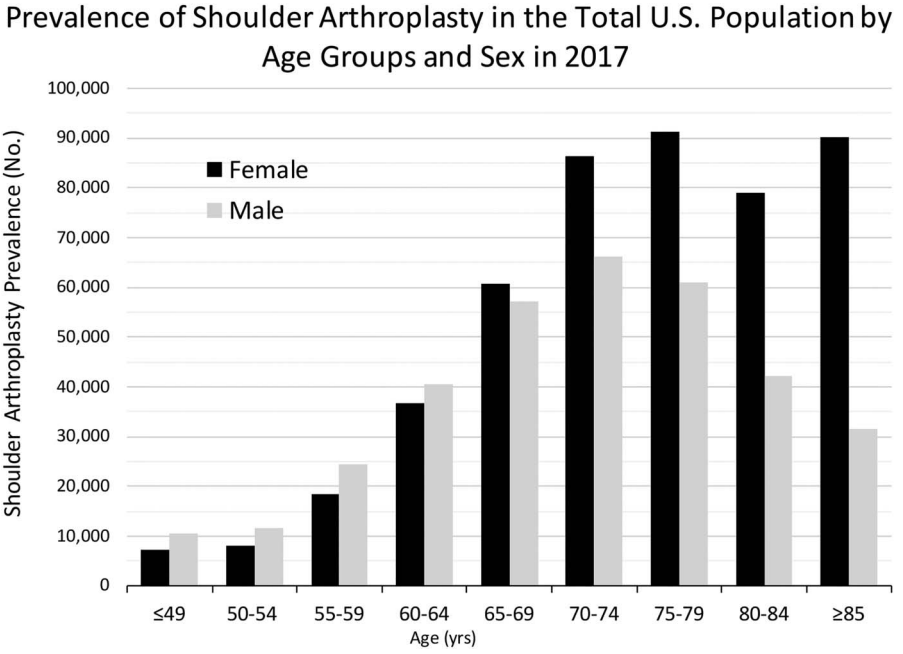

Fig. 1

Prevalence of shoulder arthroplasty in the total U.S. population by age groups and sex in 2017.

arthroplasty has historically been reserved for an older population when compared with total hip and knee arthroplasty, with improving technology and better procedural outcomes, the demand for the procedure has increased in younger cohorts[10,12].

Understanding the population of patients living after having undergone a shoulder arthroplasty has several health policy and planning implications. As these procedures are performed more frequently in a younger patient cohort and as patients live longer, the population living with these implants would be expected to increase. Understanding this population is critical to projecting the future burden of revision arthroplasty. However, the prevalence of shoulder arthroplasty within the United States, in the past or present, remains unknown. The purpose of the current study was to quantify the prevalence

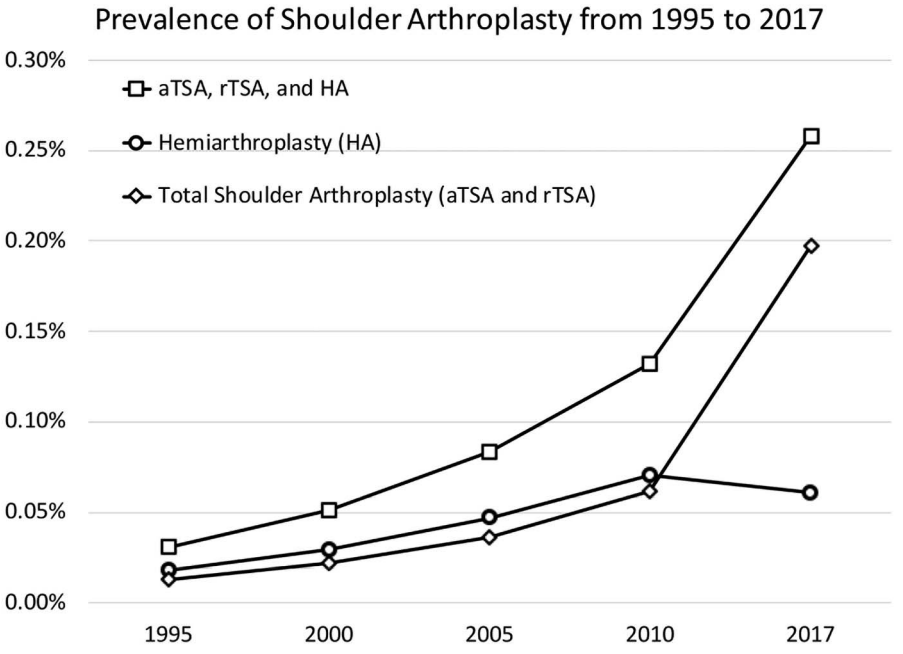

Fig. 2

Prevalence of shoulder arthroplasty from 1995 to 2017. aTSA = anatomic TSA, and rTSA = reverse TSA.

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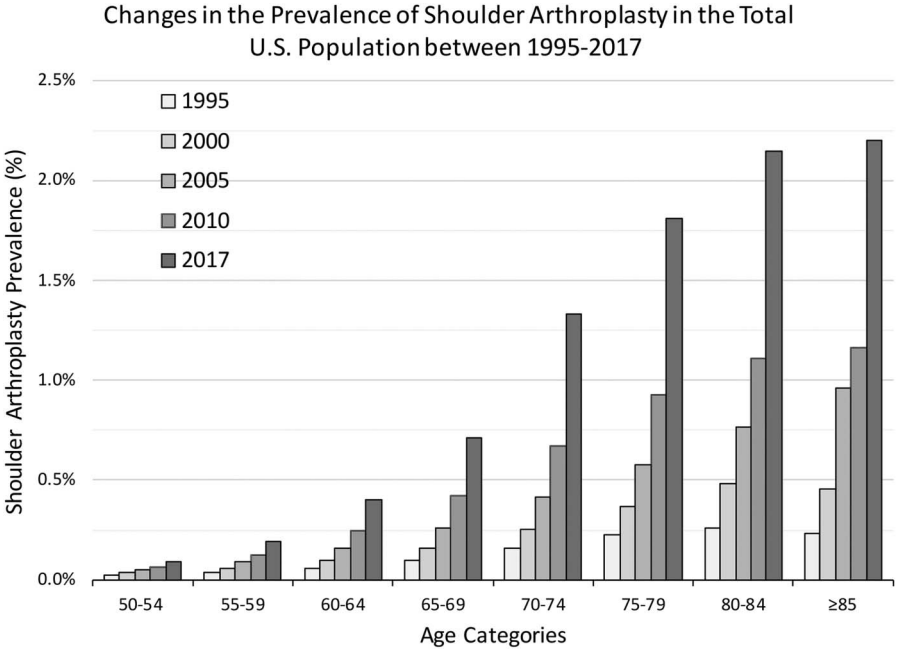

Fig. 3

Changes in the prevalence of shoulder arthroplasty (hemiarthroplasty and TSA) in the total U.S. population between 1995 and 2017 with age stratification.

of shoulder arthroplasty, including hemiarthroplasty, anatomic TSA, and reverse TSA, in the United States. We additionally aimed to examine the implications of this prevalence by describing the current trends in the procedural volume of revision shoulder arthroplasty.

Materials and Methods

A further description of the methods used for this study is given in the Appendix. Shoulder arthroplasty procedural volume data from the National Inpatient Sample (NIS), U.S. population data from the U.S. Census Bureau, and mortality data from the U.S. Centers for Disease Control and Prevention (CDC)[14] were used to determine historical and current shoulder arthroplasty prevalence in the United States. Definitions of prevalence, incidence, and procedural volume can be found in the Appendix. Data from 1988 to 2017 were utilized.

The counting method was used to estimate prevalence. Similar methodology was used previously to estimate the prevalence of total hip arthroplasty and total knee arthroplasty in the United States[13,15]. In brief, the counting method estimates the prevalence at a certain date based on the projected age of the patient and the likelihood of mortality based on actuarial life tables. Prevalence was estimated on the basis of age and sex at different time points (1995, 2000, 2005, 2010, and 2017). In addition, 2017 prevalence was estimated by U.S. Census region. Prevalence estimates by years since the index procedure (<1, 1 to 5, 6 to 10, 11 to 15, 16 to 20, and >20 years) were made. No effort was made to include revision procedures in calculating prevalence estimates, as a person with a shoulder arthroplasty remains in the prevalence pool irrespective of a revision surgical procedure. In addition, the procedural volume and the aggregate national cost of revision TSA were examined from 2002 to 2017, as described in the Appendix. All analysis was performed using SPSS, version 25.0 (IBM).

Results

Prevalence of Shoulder Arthroplasty: Total and Age Stratification

The results of this study indicate that, as of 2017, an estimated 823,361 patients (95% confidence interval [CI], 809,267 to 837,129 patients) were living in the United States after having undergone a shoulder arthroplasty. In 2017, the prevalence of TSA (including anatomic and reverse TSAs) was 0.197%, or 197 (95% CI, 193.5 to 201.3) per 100,000 people, whereas the prevalence of hemiarthroplasty was 0.061%, or 61 (95% CI, 59.7 to 61.9) per 100,000 people, and the prevalence for any shoulder replacement (anatomic TSA, hemiarthroplasty, and reverse TSA) was 0.258%, or 258 (95% CI, 253.8 to 262.5) per 100,000 people. Stratified by sex, there was a higher prevalence in female patients (0.294% [95% CI, 0.289% to 0.299%]) than in male patients (0.221% [95% CI, 0.216% to 0.225%]) (Fig. 1). The calculation of historical prevalence demonstrated a recent exponential growth in shoulder arthroplasty prevalence in the United States (Figs. 2 and 3). For instance, between 1995 and 2017, there was an increase in the prevalence of shoulder arthroplasty from 0.031% to 0.258%, with incremental increases at each time interval analyzed (Fig. 2). We also found that the prevalence of shoulder arthroplasty increased in every age cohort, even the youngest age cohort. The overall prevalence increased with increasing patient age, and the prevalence of any shoulder arthroplasty in individuals ≥80 years of age in 2017 was >2% (Fig. 3, Table I).

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TABLE I Trends in Age-Specific Prevalence of TSA and Hemiarthroplasty Between 1995 and 2017*

Procedure and Age Group	1995	2000	2005	2010	2017
Hemiarthroplasty					
≤49 yr	0.003% (5,181)	0.003% (7,069)	0.005% (9,182)	0.003% (5,412)	0.005% (9,478)
50 to 54 yr	0.015% (1,984)	0.021% (3,730)	0.030% (5,954)	0.029% (6,516)	0.033% (7,316)
55 to 59 yr	0.022% (2,404)	0.034% (4,527)	0.051% (8,744)	0.064% (12,511)	0.058% (12,595)
60 to 64 yr	0.034% (3,454)	0.053% (5,697)	0.084% (10,935)	0.135% (22,741)	0.095% (18,318)
65 to 69 yr	0.055% (5,523)	0.087% (8,323)	0.134% (13,417)	0.246% (30,635)	0.142% (23,439)
70 to 74 yr	0.085% (7,451)	0.137% (12,173)	0.216% (18,028)	0.409% (37,917)	0.239% (27,278)
75 to 79 yr	0.126% (8,291)	0.205% (15,222)	0.312% (22,728)	0.543% (39,700)	0.336% (28,291)
80 to 84 yr	0.156% (6,786)	0.273% (13,504)	0.439% (23,286)	0.593% (34,070)	0.464% (26,175)
≥85 yr	0.155% (5,461)	0.290% (12,274)	0.604% (23,023)	0.512% (28,139)	0.737% (40,880)
Total	0.018% (46,534)	0.029% (82,518)	0.047% (135,297)	0.070% (217,641)	0.061% (193,770)
Anatomic or reverse TSA					
≤49 yr	0.001% (2,265)	0.002% (3,415)	0.002% (4,175)	0.005% (10,769)	0.004% (8,373)
50 to 54 yr	0.009% (1,198)	0.015% (2,575)	0.020% (3,874)	0.038% (8,576)	0.057% (12,426)
55 to 59 yr	0.017% (1,828)	0.026% (3,557)	0.042% (7,195)	0.065% (12,710)	0.139% (30,273)
60 to 64 yr	0.027% (2,737)	0.044% (4,784)	0.074% (9,591)	0.109% (18,330)	0.305% (58,947)
65 to 69 yr	0.047% (4,654)	0.072% (6,895)	0.127% (12,769)	0.176% (21,877)	0.572% (94,498)
70 to 74 yr	0.074% (6,480)	0.118% (10,424)	0.197% (16,461)	0.265% (24,585)	1.095% (125,149)
75 to 79 yr	0.099% (6,479)	0.166% (12,308)	0.266% (19,368)	0.384% (28,111)	1.472% (123,973)
80 to 84 yr	0.107% (4,676)	0.208% (10,274)	0.326% (17,307)	0.518% (29,760)	1.684% (94,908)
≥85 yr	0.080% (2,805)	0.165% (7,006)	0.358% (13,650)	0.654% (35,909)	1.461% (81,044)
Total	0.013% (33,123)	0.022% (61,239)	0.036% (104,389)	0.062% (190,628)	0.197% (629,591)

*The values are given as the prevalence, with the number of patients within the U.S. age group and year-specific population in parentheses. The age categories from 1995 to 2017 are shown for both hemiarthroplasty and TSA (e.g., in 2017, there were an estimated 26,175 individuals who were 80 to 84 years of age with a hemiarthroplasty performed at some point in their lifetime).

Prevalence by U.S. Census Region

When considering patients >40 years of age, the prevalence of shoulder arthroplasty in 2017 was found to be highest in the Midwest at 0.682% and lowest in the Northeast at 0.426%. A similar prevalence was found between the West (0.494%) and the South (0.518%) (Fig. 4).

Prevalence and Time from the Surgical Procedure

The prevalence of TSA was analyzed with regard to time in years since the index operation. We found that the majority of people living with a shoulder prosthesis had undergone the procedure within 5 years (61.7%) or 10 years (87.4%) of the index operation. This trend was different for hemiarthroplasty, as 79.7% of the individuals had undergone the procedure >5 years after the index procedure (Fig. 5, Table II).

Revision Shoulder Arthroplasty: Incidence and Cost

From 2002 to 2017, there was an approximately 392% increase in the incidence of revision shoulder arthroplasty, from 2,216 procedures in 2002 to 10,290 procedures in 2017. Likewise, there was also an increase in the national cumulative cost of revision shoulder arthroplasty, from $26 million in 2002 to $206 million in 2017, a 685% increase (Fig. 6).

Discussion

The results of this study indicate that, in 2017, approximately 0.258% of the population was living with a shoulder prosthesis. These estimations are based on the most recent available data, and, to our knowledge, this is the first report of shoulder arthroplasty prevalence in the United States. The prevalence of shoulder arthroplasty has increased substantially over the past 2 decades, increasing by approximately 730% since 1995 (prevalence, 0.031%) and by approximately 210% since 2005 (prevalence, 0.083%). In addition to finding that >2% of individuals ≥80 years of age were living with a shoulder prosthesis, there have also been increases in prevalence in younger patient cohorts. Taken together, the rapidly growing incidence of shoulder arthroplasty, in part due to the expanding indications for its use, has led to an exponential increase in the number of people living with a shoulder prosthesis in the United States.

Several studies have examined the annual procedural incidence of shoulder arthroplasty in the United States and abroad[5-11,16-18]. Although some authors have reported incidence as prevalence (i.e., current and projected annual procedural rates)[5], to the best of our knowledge, there have been no published studies specifically examining the prevalence of

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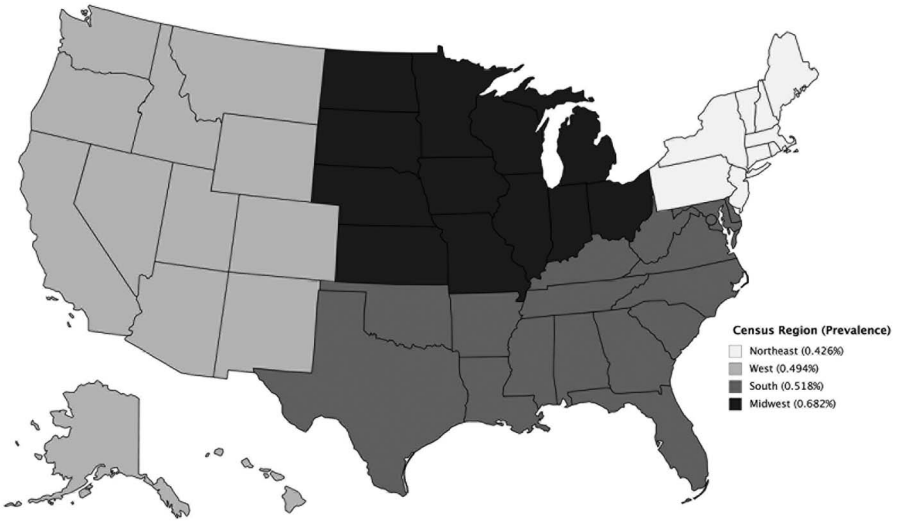

Fig. 4

The prevalence of all shoulder arthroplasty in the United States in 2017 shaded to demonstrate different levels of prevalence by Census region.

shoulder arthroplasty within the United States and the Western world. Most studies have shown the incidence (i.e., the number of procedures performed per year), but none have shown the prevalence (i.e., the number of people alive on a certain date in whom this procedure had been performed at some point in their lifetime), numbers that have different implications. All studies on incidence and projected rates[5-11,17,18] have shown dramatic increases in the utilization of shoulder arthroplasty. The rise in recent years has been attributed to the rapid adaptation and expansion of indications associated with reverse TSA[11,12,18]. We recently examined the contribution of the reverse design to the increasing incidence of shoulder arthroplasty and found that this is a substantial driver of increasing incidence, with 63,845 procedures in 2017[12].

The prevalence of total joint arthroplasty in 2010 was previously reported to be 0.83% for total hip arthroplasty and 1.52% for total knee arthroplasty[13]. Although these rates are higher than our reported 2010 shoulder arthroplasty prevalence (0.132%), the rate of growth of shoulder arthroplasty

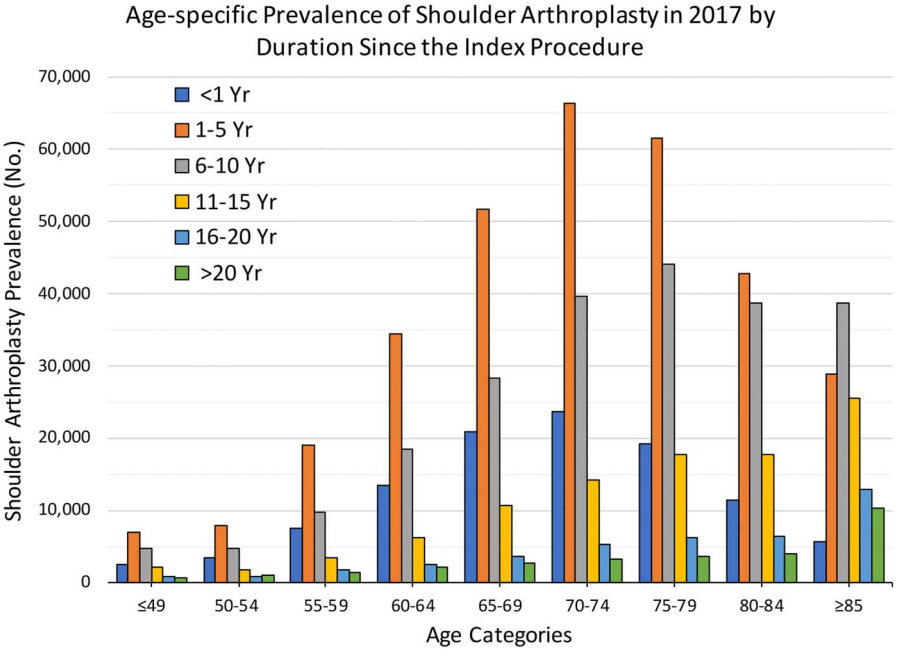

Fig. 5

Age-specific prevalence of shoulder arthroplasty in 2017 by duration since the index procedure.

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TABLE II Age-Specific Prevalence of TSA and Hemiarthroplasty in 2017 by Duration Since the Index Procedure*

	Anatomic or Reverse TSA						Hemiarthroplasty					
Age Group	<1 Yr	1 to 5 Yr	6 to 10 Yr	11 to 15 Yr	16 to 20 Yr	>20 Yr	<1 Yr	1 to 5 Yr	6 to 10 Yr	11 to 15 Yr	16 to 20 Yr	>20 Yr
≤49 yr	1,716	3,997	1,650	600	308	102	798	3,030	3,120	1,475	575	480
50 to 54 yr	2,981	5,951	2,411	570	237	276	523	1,858	2,393	1,244	648	650
55 to 59 yr	6,878	15,589	5,651	1,239	507	408	680	3,371	4,157	2,236	1,183	967
60 to 64 yr	12,642	30,026	11,958	2,649	920	752	842	4,364	6,483	3,643	1,632	1,355
65 to 69 yr	19,962	47,064	19,874	5,092	1,543	962	913	4,723	8,416	5,541	2,075	1,771
70 to 74 yr	22,812	61,651	29,477	7,643	2,289	1,276	907	4,737	10,241	6,548	2,916	1,929
75 to 79 yr	18,664	57,352	33,907	9,699	2,790	1,560	612	4,167	10,110	7,964	3,365	2,074
80 to 84 yr	10,999	39,563	29,545	10,139	2,820	1,841	343	3,195	9,184	7,661	3,557	2,236
≥85 yr	5,315	25,491	27,299	12,863	5,444	4,632	407	3,316	11,494	12,575	7,449	5,639
Total	101,970	286,684	161,772	50,496	16,859	11,811	6,025	32,761	65,597	48,886	23,401	17,100
Prevalence	16.20%	45.53%	25.69%	8.02%	2.68%	1.88%	3.11%	17.21%	33.27%	25.23%	12.29%	8.67%

*The values are given as the number of patients, except for the prevalence, which is given as the percentage of patients. Table displays the prevalence of shoulder arthroplasty in 2017 by duration since the index operation (e.g., there are 4,632 individuals ≥85 years old living in the United States with an anatomic TSA or reverse TSA that was performed >20 years previously).

prevalence is outpacing those of hip and knee arthroplasty. Between 2000 and 2010, total hip arthroplasty prevalence increased by 46% and total knee arthroplasty prevalence increased by 90%[13]. Comparatively, over the same time period, the prevalence of shoulder arthroplasty increased by 182%, and the prevalence of TSA (i.e., hemiarthroplasty excluded) increased by 159%. Our group[12] and others[6,7,9-11,18] have shown recent exponential growth in the incidence of shoulder arthroplasty, and therefore the concurrent increase in prevalence is expected.

The recent increase in incidence is further reflected in our analysis, as approximately 60% of the patients living with a shoulder prosthesis had undergone the shoulder arthroplasty within 5 years of the index procedure and approximately 83% living with a shoulder prosthesis had undergone the shoulder

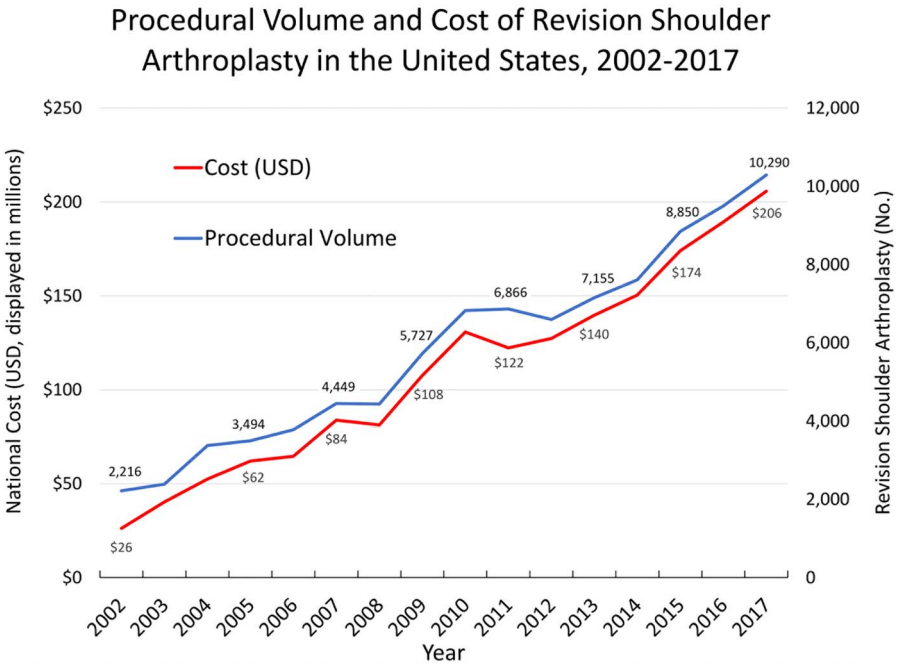

Fig. 6

Procedural volume and cost of revision shoulder arthroplasty in the United States, 2002 to 2017.

arthroplasty within 10 years of the index procedure. These numbers are higher than those reported by Maradit Kremers et al. for hip arthroplasty (65% within 10 years) and knee arthroplasty (72%). Although this reflects the increasing utilization of shoulder arthroplasty, it also highlights the accumulating number of arthroplasties that may eventually require revision, especially given the number of young patients identified in our study. For example, our age-stratified analysis for all shoulder arthroplasties showed that 133,044 patients <65 years of age living with a shoulder prosthesis had undergone the shoulder arthroplasty within 10 years of the index procedure. Because survival rates drop in younger cohorts (<65 years of age) with longer-term follow-up (approximately 20% will undergo revision at 10 years after the index procedure)[3,19-21], the potential for an escalating number of revision surgical procedures is quite clear.

These findings have multiple implications. First, the increasing prevalence, taken in conjunction with literature demonstrating good outcomes after shoulder arthroplasty[2,22-25], demonstrates the large public health benefit that shoulder arthroplasty has had and will continue to have on the U.S. population. This can be enumerated with quality-adjusted life-years (QALYs), with a patient undergoing reverse TSA for rotator cuff arthropathy having a QALY gain of 2.8 years with the cost per QALY being $11,000[26]. Although QALY and cost per QALY were increased compared with total hip arthroplasty (4.8 years, $3,900), they were still much less than the standardly accepted upper limit of $30,000 to $50,000 cost per QALY[26,27]. Second, because, currently, nearly 90% of patients living with a shoulder prosthesis had undergone the shoulder arthroplasty within 10 years of the index procedure, revision TSA volume has increased and will continue to increase. Although reasonable outcomes after a revision surgical procedure can be achieved and although the reverse TSA has made revision procedures technically less challenging than revision anatomic TSA[28-31], revision options in shoulder arthroplasty are somewhat limited in comparison with hip and knee arthroplasty, creating an ongoing need for technical and technological progress. These are all important considerations as the procedural volumes increase[31-33]. Some hopeful considerations include intermediate-term data for stemless shoulder arthroplasty (which has the benefit of bone preservation, thus potentially decreasing revision morbidity) that are equivalent to those of stemmed arthroplasty[34-36]. Likewise, developments to correct retroversion and bone loss on the glenoid side are the next steps to take toward increasing the longevity of glenoid prosthetics, but intermediate-term and long-term data on newer technologies are lacking[37]. New developments may mitigate difficulties with revision surgical procedures, and thus the cost of revision shoulder arthroplasty, in the future.

Finally, adequate surveillance of this growing number of individuals raises questions with regard to health-care resources, especially given the rising economic and clinical burden of revision arthroplasty. As the prevalence pool ages, there will be an increased demand for adequately trained orthopaedic surgeons specialized in revision shoulder arthroplasty. In ABOS (American Board of Orthopaedic Surgery) Part II candidates (board-eligible surgeons who must submit 6 consecutive months of clinical cases in order to be board-certified), the majority of primary TSAs from 2010 to 2017 were performed by non-shoulder fellowship-trained surgeons[38]. Likewise, only approximately 100 ABOS Part II candidates specializing in shoulder surgery performed primary arthroplasty over the same time period, indicating that there may be a relative shortage of surgeons optimally trained and comfortable with managing this increasing revision demand. Furthermore, the number of shoulder and elbow fellowship spots has not responded to the growing demand, remaining stable over the past several years[39]. The demand for adequately trained surgeons will need to be met over the next decade, either through increasing the number of fellowship-trained shoulder surgeons or increasing training in revision shoulder arthroplasty throughout other orthopaedic fellowships and residency.

There were several limitations to this investigation. This analysis was reliant on accurate coding. However, the NIS is a well-established database, known to contain a nationally representative sample, and therefore likely provides the best possible tool for this kind of analysis. Also, the NIS is, as its name implies, a database containing only inpatients. Given the recent trends toward outpatient shoulder arthroplasty[40-42], it is likely that our prevalence projections were slightly underestimated. In the cohorts reported by Arshi et al., approximately 10% of included patients were treated as outpatients, although this has been only a recent trend and likely affects early years minimally[42]. On a similar note, the NIS does not capture data from the Veterans Affairs (VA) Health Care system, which includes 170 centers performing major surgical procedures, and these patients were not included in our calculations. However, it is likely that the VA system performs relatively few TSAs when compared with the rest of the U.S. health-care system[43]. Lastly, the NIS first collected data in 1988, and therefore earlier years were uncaptured, which may have led to our reported results reflecting a slight underestimation.

Our results may also have been affected by assumptions made in our analysis. For instance, we assumed that patients who underwent shoulder arthroplasty experienced similar mortality rates as the general population, but this has not been definitively established[44,45]. However, it is known that patients undergoing hip and knee arthroplasty have lower rates of age-adjusted mortality secondary to the selection of healthier patients for surgical procedures[46,47]. Patients undergoing shoulder arthroplasty are, on average, slightly older and have increased comorbidity burdens when compared with patients undergoing total hip and knee arthroplasty[48,49]. Therefore, it is possible that patients undergoing shoulder arthroplasty are more similar in terms of mortality rates to age-matched cohorts that did not undergo a surgical procedure. Similarly, we did not make an adjustment for patients who underwent bilateral shoulder arthroplasty, which could have artificially inflated our estimates. However, the incidence of this scenario

is likely very low. For instance, 1 series that showed a cohort of 1,136 patients included only 16 patients who had undergone bilateral procedures (1.4%)[50]. Additionally, because of limitations in the NIS, we were not able to estimate the prevalence of shoulder arthroplasties categorized by implant characteristic or manufacturer, and this should be the focus of future work.

Despite these limitations, our use of the NIS, the largest available nationally representative sample that provides estimates on 97% of the U.S. population for all payers, represents a strength of the study. Taken in conjunction with the data that we obtained from the U.S. Census Bureau, this study uses the best and most recent data available. Furthermore, with projected increases in population alone, there will be nearly 1 million people living with a shoulder replacement in 2060. However, it is possible, if not probable, that this number will be much higher, given the known and projected increases in incidence over time.

In conclusion, a substantial number of patients are living in the United States after undergoing a shoulder arthroplasty. Given the increases in population, as well as in shoulder arthroplasty incidence, this number is likely to increase exponentially in the coming decades. Furthermore, our study more clearly demonstrates the large prevalence of young patients who will inevitably need to undergo revision. Our data indicate that most patients are within 5 years of the index procedure, and, therefore, an increased revision burden for patients with shoulder arthroplasty should be anticipated in the years to come. This information can be used by health policymakers, hospitals, and surgeons and should serve as an impetus for further investigations.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJSOA/A291). ■

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